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The injuries of four centuries of naval warfare

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Introduction

In the year 1540 Henry VIII was persuaded by his Serjeant-Surgeon, Thomas Vicary, to found the Company of Barber-Surgeons and thereby control the practice of the art, an event commemorated in the fine cartoon by Hans Holbein which hangs in the Royal College of Surgeons of England showing Thomas Vicary receiving the Charter from the King's hand. The Charter granted by Charles I in 1629 included a requirement to examine surgeons and surgeon's mates for the Navy. The Court of Examiners subsequently assumed the additional responsibility of reviewing injuries sustained in naval actions and allowing the expenses of the cure.

The need to do so had been apparent no doubt from such unfortunate affairs as that of Sir Martin Frobisher, who, after blockading Brest in 1594, had been struck by a ball from the arquebus of a Spanish soldier which lodged against the 'hucklebone'. It did not prevent him pressing home the assault, but his surgeon, who had extended the wound to extract the ball, failed to remove the wad which had been carried in with it. Gas gangrene appears to have determined the fatal outcome[1,2].

The Barber Surgeons' Company played a key role in the provision of surgeons for the fleet and, in 1704, Queen Anne expressed her appreciation by the gift of a silver punch bowl. The College of Surgeons, after its foundation in 1800, continued to examine surgeons on entry to the Royal Navy until 1843[3], when the link was severed until happily restored in 1964 by the establishment of a joint chair in naval surgery at the Royal College of Surgeons of England and the Royal Naval Hospital, Haslar.

The fighting ship

The year 1540 was also of importance to the Royal Navy for it marked the recommissioning of the great ship *Henry Grâce à Dieu* after an extensive reconstruction to accommodate the new heavy ordnance developed through Henry's liaison with Hans Poppenruyter, the gun maker of Mechlin, whom Henry, characteristically, omitted to pay. Similar guns were recovered from the wreck of the *Mary Rose* in 1836. They were breech-loading, wrought-iron bombards built up of longitudinal bars with encircling metal rings, 10 feet in length and of 8 inch calibre. There were also muzzle-loading brass cannon and culverin, similar to those in use at Trafalgar[4], except that the 1805 guns were of cast-iron, first introduced into England in 1543[5].

The *Henry Grâce à Dieu* exemplified the innovation which was a distinguishing feature of Henry's reign. When first com-

Thomas Vicary Lecture delivered on 31st October 1974

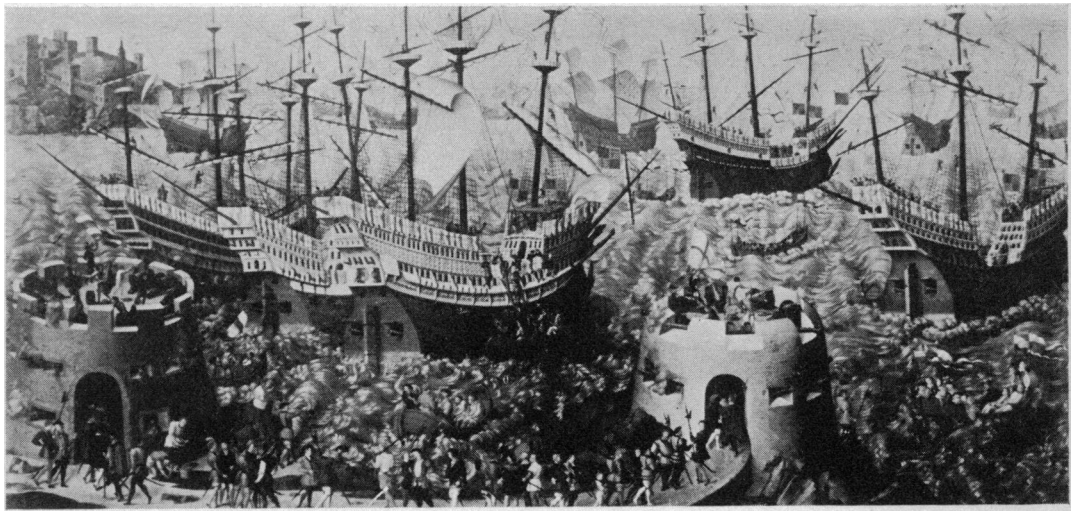

FIG. 1 *'Embarquement du Roi Henry VIII à bord du* Henry Grâce-à-Dieu, *1522.' Copy by Bouterwerke, 1844, of a painting attributed to Vincente Volpe showing the ship lying immediately beyond the tower prior to her reconstruction. (Musée de la Marine, Paris.)*

missioned in 1514 she is shown in Volpe's painting (Fig. 1) as an impressive but nonetheless typical mediaeval clinker-built vessel with ill-assorted armament, depending chiefly upon the bows of archers and primitive serpentine guns in her high fore and after castles to rake exposed enemy decks and repel boarders. Henry's influence, however, can be seen in ports for heavier guns in the ship's stern and side which Henry had compelled his shipwrights to breach against their better judgment. The Anthony Anthony Rolls[6] show that, on completion of her refit in 1540, the *Henry Grâce à Dieu* emerged with two tiers of gun ports and a formidable heavy armament (Fig. 2), the forerunner of the British broadside which was to dictate the tumblehome construction of sailing ships in order to distribute the weight of their ordnance and to endure as the principal tactical weapon of surface ships until the Second World War (Fig. 3).

Prior to the introduction of guns to ships injuries in action were sustained as the result of close fights, from the arrows of archers, from iron bars, darts, spears, and even stones hurled from the castles and, after grappling and boarding, from swords, pikes, and toma-

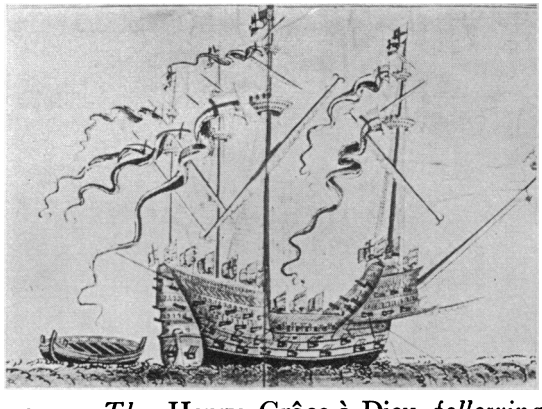

FIG. 2 *The* Henry Grâce-à-Dieu *following her reconstruction. From the Anthony Anthony Rolls, 1546. (Magdalene College, Cambridge.)*

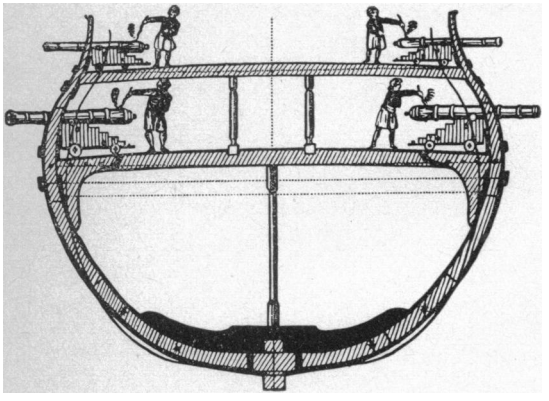

FIG. 3 *Midship section of a fourth-rate, 1684. (National Maritime Museum.)*

hawks (Fig. 4). Head and upper extremity injuries therefore predominated, but as no quarter was asked for and none given, casualties were swept overboard into the sea and there was no need for surgeons.

The Spanish Armada

The arrival of the gun coincided with the great voyages of discovery and the need to protect English overseas interests. The ship, therefore, became a self-sufficient fighting unit. The first test of British gunnery and seamanship came with the Spanish Armada in 1588, Howard wisely exploiting the handiness and greater gun range of his little ships to harry and outsail the Spaniards, conscious of the danger of close action in which the advantage would lie with the enemy, whose high castles were teeming with soldiers. These tactics proved successful, for the Spaniards' shot was spent before it reached the English ships and casualties were few, 'not above one hundred', although Drake's ship was 'pierced with shot above forty times'. 'The greatest danger', wrote Sir Richard Hawkins, 'that, as I remember, they caused to any of our shipps, was to the *Swallow* of her majestie, which I had in that action under my charge, with an arrow of fire shott into her beake-head, which we saw not, because of the sayle, till it had burned a hole in the nose as bigge as a man's head; the arrow falling out, and driving alongst by the shippes side'[7]. These early arrow projectiles were bound in leather to fit into the bore, but were quickly succeeded by stone, then cast-iron round shot[8].

The significance of that incident was not lost upon Wylliam Clowes, who appears to have been in Howard's flagship, the *Ark Royal* (Fig. 5), and was no doubt highlighted for him at Gravelines when Howard sent in fireships to drive the terrified Spaniards to

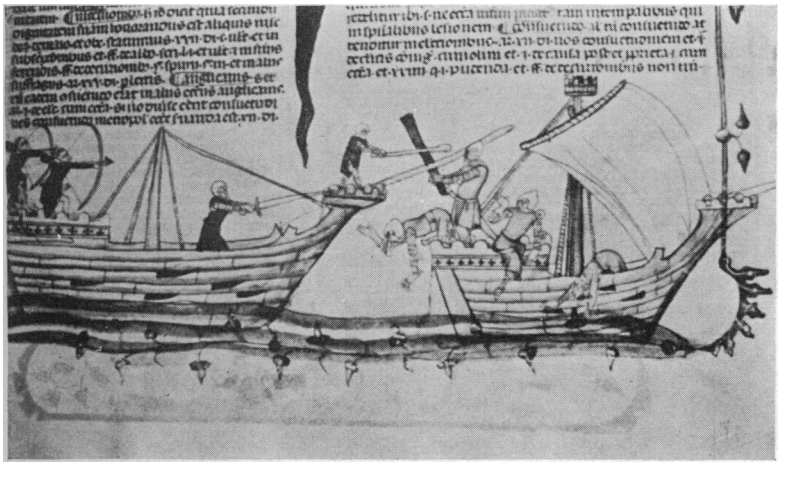

FIG. 4 *A close fight at sea in the 14th century. (MSS 10E, IV. British Museum.)*

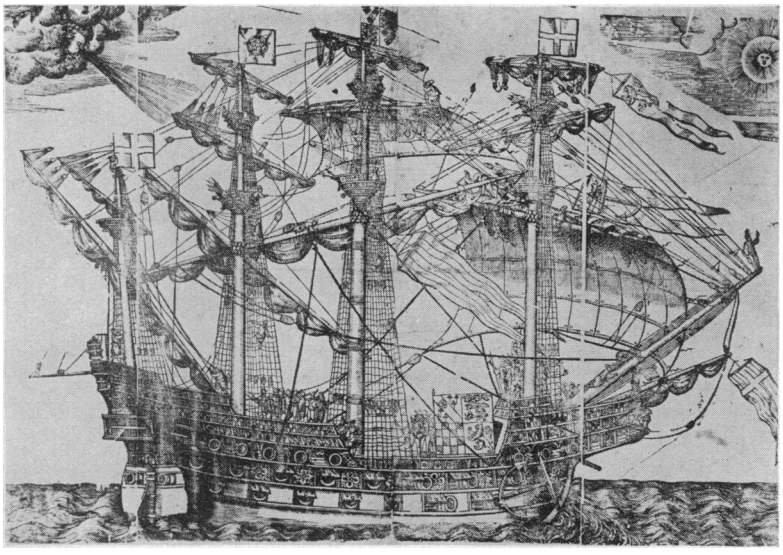

FIG. 5 *The* Ark Royal, *Howard's flagship in the battle against the Spanish Armada, 1588, bought by Queen Elizabeth from Sir Walter Raleigh. (The Mansell Collection, London.)*

sea in confusion. It is therefore scarcely surprising, in that Armada year, that Wylliam Clowes[9] should publish *An Approved Practice for all Yong Chirurgians concerning Burnings with Gunpowder . . .* Clowes distinguished between partial and full-thickness skin loss, using wet, cooling lotions for superficial burns and oily dressings or creams for full-thickness loss, with attention to fluid replacement with 'boyled water' in the initial stages and to nutrition during convalescence. His results appear to have been successful and rehabilitation was not neglected, for the recently healed burn was gently massaged with egg yolks and almond oil.

Burns

The Armada drew attention to the complicated nature of burn injuries. There were superficial flash burns from the accidental ignition of powder horns used for priming the guns or of loose powder strewn over the deck. There were localized full-thickness burns from sudden bulging of over-heated brass culverins, burn wounds of the head and face from misfire of wrought-iron breech-loading guns with ejection of the hot breech box, and burn wounds of the body from hot fragments of exploding cast-iron muzzle-loaders.

Burns continued to dominate the writings of naval surgeons for the next century. To John Woodall[10] we owe the principle of enzymatic debridement and the important instruction to 'take away all the powder that sticketh to the flesh, for it hindereth the cure' and to John Moyle[11], who was then describing severe contractures following burns at sea, the early surgical debridement practised today. A century later, however, Blane[12] and Turnbull[13] were reporting a high burns mortality and it is interesting to speculate that toxic absorption of 'cerussa', a lotion of lead dissolved in vinegar then in general use in the Navy as a local application, was responsible for this.

The enormity of the burns problem was even more evident to the enemy as whole ships' companies disappeared in terrifying explosions. *L'Orient* at the Battle of the Nile threw great burning beams over *Alexander* and *Swiftsure* and John Nicol, a seaman in

HMS *Goliath,* describes the scene which met his eyes when he went on deck after the action: 'The whole bay was covered with dead bodies, mangled, wounded and scorched, not a bit of clothes on them except their trowsers'[14]. Charles McPherson[15] records that, at Navarino in 1827, pieces of burning wood and showers of burned rice and olives rained in profusion from burning Turkish ships and that 'a Turkish ship of the line exploded showering iron, wood and nails' over the *Genoa.*

Ship- and man-destroying missiles

The Dutch wars of the 17th century provided a pattern of injury from actions at sea which changed little during the sailing ship era and Wiseman[16], writing just after the third Dutch war, drew attention to the gross soft-tissue injuries then being experienced. 'In our sea-fights, oftentimes a buttock, the brawn of the thigh, the calf of the leg are torn by shot and splinters. All these are contused wounds and look black and do often deceive the inexperienced chirurgeon, he taking them by their aspect to be gangrened.' Going on to describe their subsequent course, he observes that they 'look like flesh long hang'd in the air, of a dry, blackish colour, yet they have warmth'. They subsequently discharged massive sloughs leaving indolent ulcers and huge tissue defects.

Because of its weight and velocity, solid round shot became the principal ship-destroying projectile. It also splintered hull and masts to provide secondary anti-personnel missiles. Double-headed bar, telescopic, and chain shot were intended to cripple enemy sailing power, but were not much favoured by the British because of their inaccuracy. They were, however, responsible for many of the injuries sustained by British seamen aloft or on the exposed upper deck. Primary man-destroying missiles were canister or case shot (a cylindrical tin case containing small, loose, iron balls), langrage (a tin filled with scrap and iron bars), and grape or quilted shot (iron balls arranged round an iron column in a canvas bag). They also proved useful in cutting chain plates, stays, and shrouds[17] (Fig. 6).

The number of compound fractures and traumatic avulsions of limbs made naval surgeons adept at amputation and, contrary to popular opinion, the arrest of haemorrhage was by forceps or ligation and not by the red hot cautery roundly condemned by James Yonge[18] in his *Currus Triumphalis* published in 1679 while surgeon at the Naval Hospital, Plymouth. He also condemned the practice of blood-letting, and the work is noteworthy on two accounts. He describes controlled experiments in dogs showing the superiority of oil of turpentine over the ligature in the arrest of haemorrhage, which he assessed by measuring clotting times and by microscopic evidence of vessel and clot retraction. He also devised a posterior flap technique for amputation of the lower limb which, he claimed, accelerated healing and avoided bone necrosis and ulceration of the stump. Another notable improvement in amputation technique was the cutting of ligatures short, first practised by Lancelot Haire[19] while an assistant surgeon at the Naval Hospital, Haslar, in 1786.

The British usually double-loaded with solid shot and grape or canister with the object of smashing the enemy's hull and killing or wounding her gunners. They therefore fired on the downward roll, while the enemy, intent on immobilizing the British ships, aimed bar and chain shot at yards or rigging on the upward roll[20]. These different tactics, as we shall see, were to determine the different casualty patterns of the combatants in the wars with France.

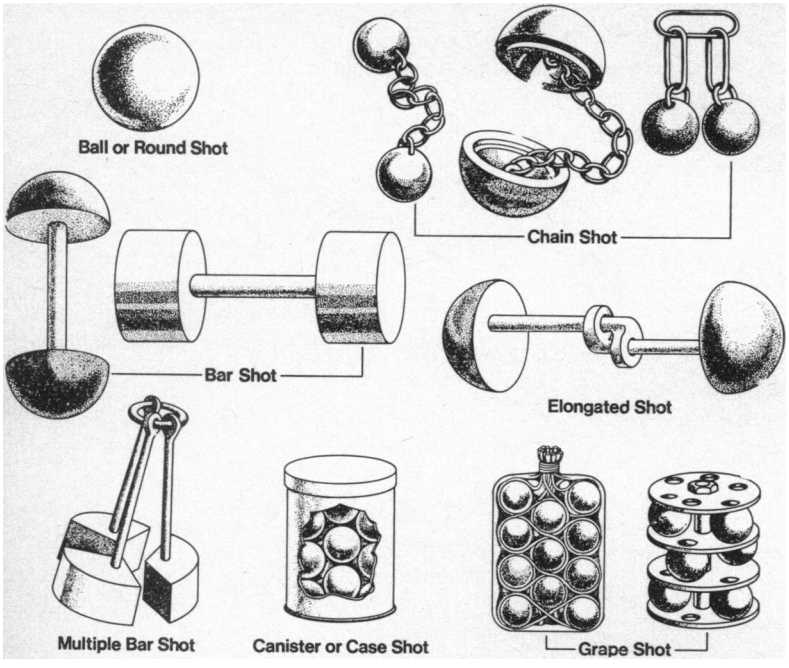

FIG. 6 *Shot used in naval cannon during the sailing ship era. (H Tomkins after an illustration by R Woodward.)*

Round shot Round shot, of course, was the most mutilating, causing dismemberment and evisceration. McPherson[21] describes how, at Navarino, he saw a midshipman knocked clean out of the top, hanging by the intestines from the boat's davits, and Gardner[22] recalls that 'one of our poor fellows was cut in two by a double-headed shot on the main deck, and the lining of his stomach (about the size of a pancake) stuck on the side of the launch'. A similar fate befell de Brueys in *L'Orient,* his flagship at the Nile, when a shot carried off both legs. He had himself placed in an armchair on deck with tourniquets on both stumps until a cannon ball cut him in half[23].

'Wind of a ball' An injury which greatly puzzled the naval surgeon was what he described as 'wind of a ball' or the near miss of a cannon ball which caused the affected part to become 'livid and benumbed' while, if the shot grazed the abdomen, it could prove instantly fatal without the least mark of injury[24]. John Nicol[25] describes a typical case at the Battle of the Nile: 'One lad who was stationed by a salt-box, on which he sat to give out cartridges, and keep the lid close—it is a trying berth—when asked for a cartridge he gave none, yet he sat upright; his eyes were open. One of the men gave him a push; he fell all his length on the deck. There was not a blemish on his body, yet he was quite dead, and was thrown overboard'. Dillon[26] tells how he was knocked unconscious at the Battle of the Glorious First of June in just such a manner and in the painting by Mather Brown of that battle (Fig. 7) Sir Andrew Snape Douglas (far right) is swaying unsteadily, temporarily concussed by a near miss, while Captain Neville of the Queen's Regiment (right centre) is shot through the chest and mortally wounded.

FIG. 7 *Lord Howe on the quarterdeck of the* Queen Charlotte *at the Battle of the Glorious First of June, 1794. (Painting by Mather Brown in the National Maritime Museum.)*

Grape shot Patrick Renny, surgeon of the *Coventry* at the Battle of Quiberon Bay, 1759, describes his visit after the battle to the French prize *Formidable,* whose starboard side had been 'pierced like a cullender' by British shot. She had over 500 casualties and the grand chamber was strewn with wounded officers, tourniquets still screwed on amputation stumps, and every space below decks crammed with wounded soldiers and sailors. Renny was asked to advise on the wound of an officer caused by grape shot which had penetrated the thigh, fractured the femur, ballooned the scrotum, and carried away the rectum with the buttock[27]. This was unusually severe, and those who survived grape-shot wounds more often sustained localized compound fractures of the extremities.

Boteler[28] at Navarino describes a typical case: 'Young Grey . . . was in the act of giving the Captain of the Gun some grape-shot, when he turned round, laughing to see the grape scattered on the deck. I saw what it was, and he too directly also. He turned pale and said "Oh Sir, it is my right arm". He was taken below and the arm amputated, but the next day Dr Hillyer found the bone splintered higher up . . . and it was taken out of the socket. . . . At the naval hospital, Malta, he had lockjaw but got over it'.

Robert Mercer Wilson[29] in his journal described the action in the Bay of Naples in June 1809 between the French frigate *Cérès* and the English ship *Cyane* where 'the grape-shot flew like hailstones' and *Cérès* had over 50 men killed. Descamps, who accompanied Murat on his visit to the ship after the action, graphically depicted some of the injuries in a painting which hangs in the Musée de la Marine, Paris (Fig. 8). The surgeon is dressing a sucking wound of the chest with a pad and bandage, a barrel bandage has been applied to a fractured jaw, and there are a grave abdominal wound and head wounds. It was following this battle that Murat told Napoleon: 'C'est le premier combat de marine que j'ai vu et j'avoue qu'il ne faut pas être moins brave sur mer que sur terre'.

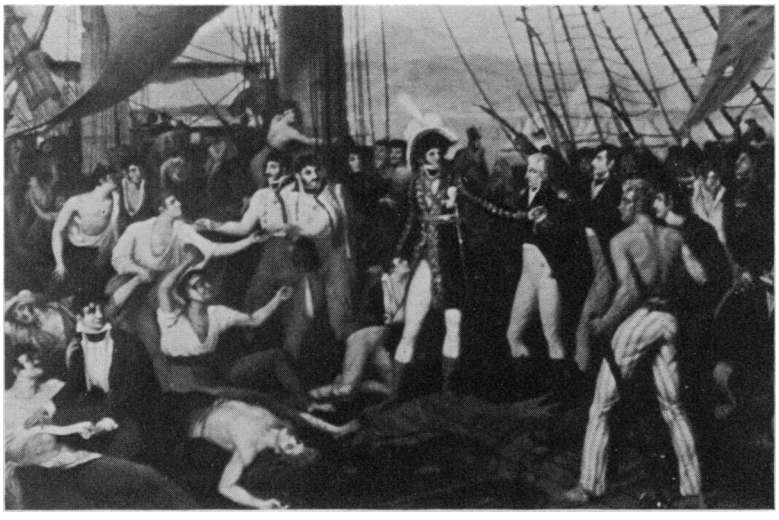

FIG. 8 *Painting by Descamps who accompanied Murat (centre) on board* Cérès *after her battle with* Cyane *in the Bay of Naples, 27th June 1809. (Musée de la Marine, Paris.)*

Splinters Hutchinson[30], writing at the end of the Napoleonic wars, draws a distinction between the localized wounds from grape shot and musket balls inflicted by confronting armies and the extensive injuries caused by a direct hit from the round shot of a ship's cannon or by 'ragged fragments of timber violently rent from the planks or sides of the ship'. He adds, 'wounds inflicted by splinters of wood are always more extensive, accompanied with frightful contusions and lacerations of the soft parts', and Wiseman[31] had pointed out that even if the splinter had insufficient velocity to cause a wound 'it sometimes bruiseth the skin to the flesh so forcibly as to extinguish the naturall heat and make it black', producing an eschar which would separate to leave an indolent ulcer, possibly of 'Meleney' type, and finally an ugly scar. A painting by Drummond of the Battle of Camperdown clearly displays hypertrophic and keloid scars in seamen of the period (Fig. 9).

The extensive contusions and blackened, unhealthy nature of wounds, to which frequent reference is made, was due largely to the prevalence of scurvy in the British fleet which, in times of war, remained at sea for long periods. This led to a number of complications such as generalized oozing from amputated stumps, adding greatly to the anaemia resulting from initial blood loss. Cumming[32] appears to have treated a number of patients with this complication after Copenhagen in 1801 and was compelled to use graduated tow compresses and firm roller bandaging to control bleeding from the stumps. A greater problem, however, was the traumatic ischaemic contracture resulting from collections of blood below the deep fascia, often confused with gangrene. Amputation usually resulted, although Turnbull[33] attempted to treat the condition by burying the limb in earth—perhaps the original mud pack! Hutchinson[34] finally recognized the true nature of the condition, which he called 'erysipelas phlegmonodes' and distinguished it from 'erysipelas oedematodes', which seems to have been gas gangrene. He rightly adduced the stiffness and rigidity resulting from the former as due to adhesion between the muscles, tendons, and their sheaths as the result of effused blood and, at the naval hospital at Deal, practised multiple incisions

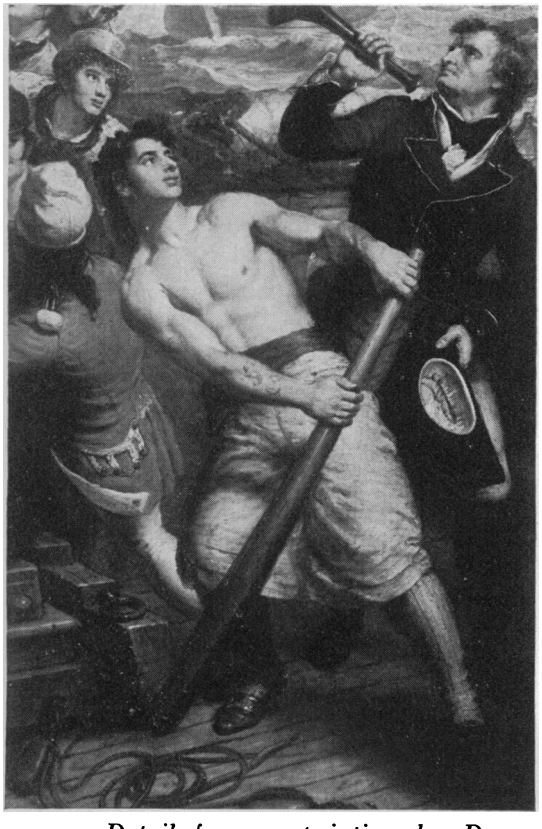

FIG. 9 *Detail from a painting by Drummond of the Battle of Camperdown, 11th October 1797, showing large keloid scars of left forearm and shoulder in a seaman aboard the* Venerable, *flagship of Admiral Duncan. (National Maritime Museum.)*

through skin and deep fascia followed by gentle massage and active movements. His patients all recovered, free from infection, with full restoration of function. He was over 100 years ahead of his time, although John Moyle[35] had recorded a similar surgical approach in a single case of subfascial haematoma which formed in the leg of a sailor caught in the bight of a cable over 100 years previously.

Boarding

The Battles of Barfleur and La Hougue in 1692, which frustrated the attempt by the exiled James II to invade England with the help of the French fleet, contained all those ingredients of naval actions to provide the broadest possible spectrum of injury. At Barfleur Tourville was decisively beaten by Shovell's superior gun power and, under Rooke, an armada of 200 small boats from the British fleet swept into La Hougue harbour two days later, in the face of murderous fire from the protecting batteries, to board and fire six French three-deckers and set the harbour ablaze.

No doubt with that episode in mind John Moyle[36] wrote his *Chirurgus Marinus,* for it turns out to be a description of the cockpit of a man-of-war and a case book of injuries dealt with by the surgeon and his mates, typical of just such an action. The chief interest is in wounds sustained by boarding parties from cutting or hacking weapons and small arms such as muskets and pistols (Fig. 10). The typical cutlass wound is described as an oblique incision across the wrist dividing vessels and nerves and requiring immediate suture which must avoid picking up nerve or tendon. Wounds from the tomahawk carried by boarding parties were confined to the head and face and might slice the cheek away from the bone. Pikes were commonly run through the chest and, if they missed vital organs, left a track which required daily syringing and adequate drainage. A rapier or the bullet of a pistol often passed through the throat, requiring through-and-through drainage with haemorrhage difficult to control unless the blood pressure was dangerously lowered by blood-letting.

Among contemporary accounts of boarding episodes Wilson[37] describes how sailors from the frigate *Unité* boarded Turkish vessels in the port of Durazzo in the Adriatic through

FIG. 10 *'Progress of a Midshipman'. Cartoon in the National Maritime Museum of pirates boarding one of HM ships.*

a barrage of grape shot and musketry, running the enemy through with their boarding pikes, normally a defensive weapon. Boteler[38] recalls that, at Navarino, the spritsail yard of a Turkish frigate crossed *Albion's* poop. Immediately the first lieutenant led a party of volunteers with swinging cutlasses and the butts of marine muskets to sweep the deck of Turks, who continued shooting from below until the boarders seized cannon balls and rained them down upon their hapless victims. A Turk in the foretop picked off the arm of the boatswain with a musket shot and three British sailors sprang nimbly up the rigging and threw the Turks overboard. Later the surgeon of *Albion* came across a Turk who had apparently followed the boarders back. He was dying from a typical tomahawk wound which had sliced through the occiput. Height was still, on occasion, as important as in the old castellated ships. Nelson was shot through the chest at Trafalgar by a marksman in *Redoubtable's* top (Fig. 11), and a similar injury befell a mariner in *Ardent* at Camperdown in 1797 but with a happier result for, according to Young[39], the ship's surgeon, about a month afterwards, following a violent fit of coughing, he 'brought up part of a check shirt and flannel waistcoat after which he daily continued better'.

But height also had its problems and contributed to the casualty list. Apart from accidental falls in relatively fit men aloft there were problems for the wounded seamen reaching the deck below. Stenhouse[40], surgeon of the *Glasgow* at the Battle of Algiers, describes the case of the captain of the foretop who had his leg carried away by a cannon ball except for a strip of tissue by which it was attached. He grabbed a rope to lower himself on deck, but half-way down his flail limb became entangled among the rigging and he was obliged to pull himself up with his arms and disengage the wounded limb with the assistance of the sound one. He then quietly descended on deck and reached the cockpit at the moment when the bugleman's wife, who was attending the wounded, heard her husband had been killed by a cannon ball. The wounded seaman was quick to comfort her: 'Come on, Poll', he said, 'cease to grieve; you shall not remain a widow long'. And he kept his promise!

FIG. 11 Victory *at Trafalgar 1805 by Dighton (National Maritime Museum). Nelson wounded by a bullet from a rifled musket fired from the mizzen-top of the French flagship* Redoubtable *which penetrated the left lung and injured the left pulmonary artery and spinal cord.*

Accidents

Throughout the sailing ship era accidents continued to contribute significantly to the casualty rate. A typical incident is related by Samuel Leech[41] in his account of the battle between the *Macedonian* and the American frigate *United States* in 1812. A powder boy on the quarter deck was killed when 'his powder caught fire and burnt the flesh almost off his face. In this pitiable situation the agonised boy lifted up both his hands, as if imploring relief, when a passing shot instantly cut him in half'. Such accidents also led to mass casualties. At Camperdown (Fig. 12) Young[39], surgeon of the *Ardent* and without an assistant, found himself dealing with 90 casualties piled one upon the other at the foot of the ladder leading to the cockpit. Almost fainting from fatigue, he struggled manfully through the amputations in the stiflingly hot atmosphere when, he writes, 'an explosion of a salt box with several cartridges abreast of the cockpit hatchway filled the hatchway with flame and, in a moment, fourteen or fifteen wretches tumbled down upon each other, their faces black as a cinder and clothes torn to shatters and the rags on fire . . .' There were 41 killed and 107 wounded out of a ship's company of 485, a casualty rate of 30.5%.

Blane[42] informs us that 'in the battles of 1780 and 1781, one-fourth part of the whole killed and wounded was from the explosion of gunpowder; but on the 9th and 12th April 1782 (Battle of the Saints), only two accidental explosions of gunpowder happened

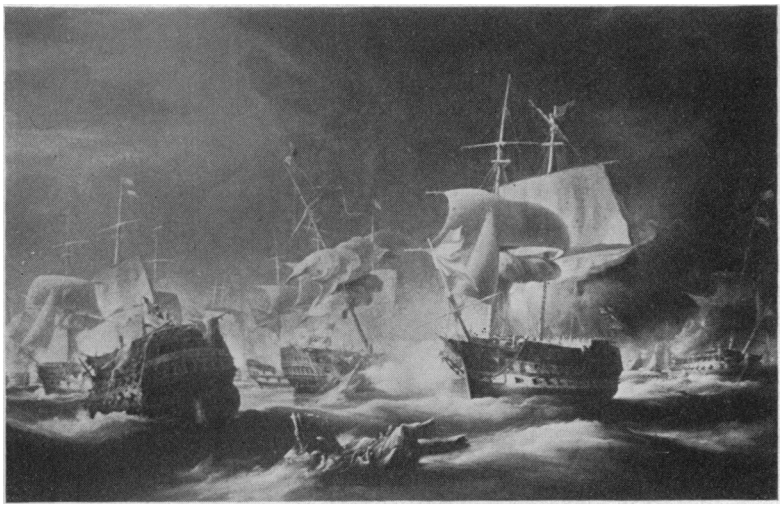

FIG. 12 *Battle of Camperdown, 1797, by William Huggins in the Army and Navy Club, Pall Mall, London. The stern of* Ardent *can just be seen in the background, left of centre.*

in the whole fleet, by one of which, one life was lost, by the other, two'. He attributed this to the better training of guns' crews and safety measures introduced by Sir Charles Douglas. They included wetting the wads which, when the weather side of the ship was engaged, used to blow back and ignite the gunpowder, replacement of the large ox horns which held the loose powder by goose quill tubes, and small priming boxes. It was Douglas, too, who first used gun locks at sea, which increased operational safety.

The mishandling of guns was the other main cause of accidental injuries. According to Inman[43] too great a charge and overloading of guns caused straining of the carriage, breaching, tackles, and side bolts and increased recoil, while overheating resulted from the rapid rate of firing achieved by the highly efficient British gunners. Failure to ram home the shot on the head of the cartridge in the heat of action caused the gun to burst or to be dismounted. There is abundant evidence that all these factors operated in sea battles and caused numerous burns, wounds, and fractures, while shot fired from the short muzzles of the deadly British carronades or 'smashers', introduced into the fleet in 1779, often set on fire the ship's own sails and rigging. *Albion* was twice set on fire by her own carronades at the Battle of Navarino, and Boteler[44] records that all gunners invariably overloaded, 'nearly always with two shot, sometimes with three'. One was even found with four round shot. Not surprisingly 'the guns were very lively springing back from their breachings and jumping off the deck'. When a hide lanyard broke, which fired the flintlocks then in use, Midshipman Boys jumped to the breech and pulled the trigger, only to be struck in the stomach by the gun's violent recoil. Though he was 'long unconscious', the surgeon could find no trace of external injury. The casualties resulting from such incidents were by no means insignificant, for Edward Daubeny, in a letter to his father from HMS *Bellona* after the Battle of Copenhagen in 1801, writes that 'we have besides above eighty killed and wounded by the bursting of our guns'[45]. Midshipman Anderson, who was also on board *Bellona,* explains the sequence of events in which he himself was injured by shrapnel from one of them[46]. Although only a soft-tissue injury, the surgeon, evidently from long experience, warned him that it

would be three months before he fully recovered.

Morale

The explosion of guns had a disastrous effect upon the morale of the ship's company[47]. When one of the 12-pounder guns burst in the British frigate *Ambuscade* while engaging the French corvette *Bayonnaise* in December 1798 11 men were wounded and the ship seriously damaged. The French, who had already suffered heavily from the English broadside, rammed *Ambuscade* (Fig. 13) and French soldiers swept her deck with musketry. Five officers were killed or wounded by bullets and the purser took command. At that moment an explosion of cartridges on the rudder head blew out *Ambuscade's* stern and so demoralized the crew that French boarders were able to charge across the spritsail yard to carry *Ambuscade's* deck. Yet such was the destruction wreaked upon the French vessel that the captured English frigate had to tow its captor back to Rochefort! Casualty statistics are revealing for, while the casualty rates were comparable (24.0% in the French vessel and 26.3% in the English), the ratio of killed to wounded amongst the French was 1 : 1 but among the English it was 1 : 4, an indication of the destructive potential of the British carronade and the fighting qualities of the British seaman in hand-to-hand encounters.

Entanglements, of course, were inevitable in close engagements, yards and rigging often locked inextricably, a fate which befell *Seraphis* off Flamborough Head in 1779 when she engaged the *Bonhomme Richard* commanded by the American privateer, John Paul Jones. The two ships found themselves bow to stern, gun muzzle to gun muzzle, which drove Jones's men from their guns to the tops, while the 18-pounders of *Seraphis* blasted through their own closed gun ports to reduce the American's hull to shivers and set her own starboard side fiercely ablaze. After boarding and counter-boarding, height again proved useful to an American seaman who climbed out along his own yard to drop a bucket of hand grenades down the main hatchway of *Seraphis* and into her gun room, where they caused a violent explosion which ran aft between the rows of guns, dis-

FIG. 13 *The French corvette* Bayonnaise *ramming and boarding the English frigate* Ambuscade, *14th December 1798. (Painting by L-Ph Crépin in the Musée de la Marine, Paris.)*

abling five and scorching and wounding 38 men[48]. The Americans, taking advantage of the dismay and shock, rushed the deck of *Seraphis* to win the day, although *Bonhomme Richard* was so battered that she soon sank. The casualty rate was 38.4% in the victorious *Bonhomme Richard* and 48.8% in *Seraphis,* with a killed to wounded ratio of 2 : 3 in both ships, indicating comparable standards of gunnery and fighting qualities.

Sir Gilbert Blane[49] in his *Health of the Royal Navy* considered that the superior physique, courage, and discipline of the English seamen gave them the edge over the French in close action, where more shot were effective. He gave the ratio of killed to wounded in the French wars as 1 : 3, but varying according to distance and the charge of powder. This observation is borne out by casualty patterns in six of the major battles of the Nelson era for, while the casualty rate varied considerably, the ratio of killed to wounded remained at about 1 : 3 (Table I).

The Battle of Algiers

This interest in casualty patterns is exemplified by Hutchinson's[50] well-documented record of the Battle of Algiers in 1816. He was struck by the marked difference in mortality rates following amputations performed on board the various ships and persuaded the Commissioners for Transports to send a questionnaire to each of the surgeons asking them to specify the number and nature of wounds requiring amputation, whether amputation was immediate or deferred, the duration of delay in minutes, hours, or days, the number who recovered or died, and the period of survival.

What emerged was interesting. By far the greatest number (83%) had been injured by cannon shot and only 8.5% by splinters and 8.5% by musket balls—no doubt indicative of the effect of high-velocity round shot from the cannon of the defending forts. The surgeons who practised immediate amputation not only dealt with more serious injuries but also carried out more amputations per patient, yet their mortality rate (33.3%) was significantly lower than that of the delayed group (45.8%) (Table II). Moreover, two deaths in the immediate group were caused by conditions other than the amputation. Hutchinson[50] made important recommendations for amputation, including obliteration of dead space and transverse closure of the stump instead of the usual vertical closure, which tended to open an infected track inferiorly. Although 'the locked jaw' was a common and usually fatal consequence of wounds in action, Hutchinson[50] records only one case,

TABLE I *Casualty patterns in six major battles in the Nelson era involving ships of the line (1794–1805)*

Battle	*Force*	*Killed*	*Wounded*	*Ratio killed:wounded*	*Casualty rate (%)*
First of June, 1794	17 241	287	811	1 : 3	6.37
St Vincent, 1797	11 046	73	227	1 : 3	2.72
Camperdown, 1797	8221	203	622	1 : 3	10.03
The Nile, 1798	7985	218	678	1 : 3	11.22
Copenhagen, 1801	8565	253	688	1 : 3	10.99
Trafalgar, 1805	17 772	449	1242	1 : 3	9.51
Total	70 830	1483	4268	1 : 3	8.12

TABLE II *Battle of Algiers 1816: results of immediate and delayed amputation*

	No.	*Amputations*	*Cases* *Hip*	*Above knee*	*Below knee*	*Shoulder*	*Above elbow*	*Below elbow*	*No.*	*Deaths* *Shock*	*Sepsis*	*Tetanus*	*Other*
Delayed treatment													
Impregnable	11	11	–	4	3	2	1	1	9	6	2	1	–
Granicus	5	5	–	–	–	2	2	1	1	1	–	–	–
Infernal	1	1	–	1	–	–	–	–	–	–	–	–	–
Queen Charlotte	7	7	–	2	1	1	2	1	1	–	1	–	–
Total	24	24	–	7	4	5	5	3	11	7	3	1	–
Immediate treatment													
Glasgow	3	4	–	1	–	–	2	1	1	–	–	–	1
Superb	1	1	–	1	–	–	–	–	–	–	–	–	–
Leander	14	16	1	10	–	–	3	2	5	3	1	–	1
Total	18	21	1	12	–	–	5	3	6	3	1	–	2

probably because of the low incidence of splinter wounds, but at the Saints Blane[51] states that 15 of 67 wounded seamen who died on board their ships after the battle died from tetanus and that some surgeons held that ligatures were responsible and so preferred the 'tenaculum'.

End of an era

Wilson[52], writing at the end of the sailing ship era, paints a picture of the cockpit little different from that of Moyle in 1693[36]: 'Death and wounds in every shape, limbs lacerated or torn off—wounds from muskets or splinters—bayonet or cutlass wounds, everything, in short, appalling or horrible and all, probably, in a few minutes, in the midst of bustle, the noise of guns, the close atmosphere and . . . candlelight'. This caused him to propose a system of sorting of casualties into three categories—slight, serious, and fatal. His recommendations have a strikingly modern ring for he argued that immediate life-saving surgery could be brought to severely injured casualties only if treatment for slight injuries was deferred and only palliative measures adopted for injuries likely to prove fatal. Had this advice been followed in the century of the iron warship it would have saved many more lives.

Before leaving the age of sail, however, it is necessary to pay tribute to two other naval surgeons—David Fleming, who carried out the first successful ligation of the common carotid artery on board HMS *Tonnant* in 1803[53], and Ralph Cumming, who in 1808 performed the first successful forequarter amputation at the Naval Hospital, Antigua[54]. To these names, I believe, should be added that of James Lind[55], the most illustrious of them all, who conquered scurvy and proclaimed the principles of hygiene which provided captains with the fit men they needed

to win their battles. Blane[56] considered that over 6,000 lives had been saved each year by these measures. Lind was a remarkable man and two of his inventions, had they been accepted by the Admiralty, might have revolutionized naval warfare of that era. They were distillation of water at sea and rifling of guns[4].

The age of transition

The Battle of Hampton Roads in 1862 between two mastless ironclads, the converted Confederate frigate *Merrimack* and her turretted Federal opponent *Monitor,* proved the value both of armour plate and the revolving turret. Britain, quick to learn, launched the first mastless battleship, HMS *Devastation,* in 1871, the forerunner of all subsequent warship construction, her four muzzle-loading 12-inch guns firing 700-lb shells supplied to the steam-revolving turrets by the Armstrong hydraulic system.

By the end of the century naval surgeons had had enough experience of the new ship construction to recognize the nature of the hazards to which men would be subjected in action. The piercing power of the shell had doubled to expose men, now concentrated in the confined spaces of turrets and their supply routes (Fig. 14) and in the new engine and boiler rooms, to splinters of steel, blast from explosions, and the disintegrating forces of a direct hit. Men would now be hurled against steel bulkheads and projecting machinery or struck by detached components acting as secondary missiles. Rivets might be stripped and their heads showered over the ship's company[57] and, in HMS *Furious,* this even occurred when she fired her own 18-inch guns. Guns could still misfire but with far worse consequences, and when a 12-inch gun muzzle exploded in HMS *Thunderer,* sister ship to *Devastation,* in 1879 nine men were killed and 35 injured, only one man in the turret surviving[58]. This led to a return to breech loading with its attendant accidents—hands jammed in the breech or men struck by parts of the mechanism.

Accidents in the new engine and boiler rooms pointed to a high incidence of burns from burst boilers or fractured steam pipes. When one of the boilers burst in HMS *Thunderer* in 1876 13 men were killed and 49 admitted to the Royal Naval Hospital, Haslar, with what Fleet Surgeon Harkan[59] described as 'the most severe scalds that could possibly be sustained, the skin being mostly dissected away and hanging in flaps about their body; face and eyelids completely destroyed in the majority of cases and many sinking rapidly under the shock'. A similar catastrophe befell the destroyer *Bullfinch* in 1899. While she was travelling at 30 knots a high-pressure connecting rod broke, the cylinder fractured, and a bolt was shot through the bottom of the ship. Eleven men in the compartment were scalded to death[60]. Burns remain one of the most serious injuries in modern warships.

The First World War

The Medical Director General of the Navy

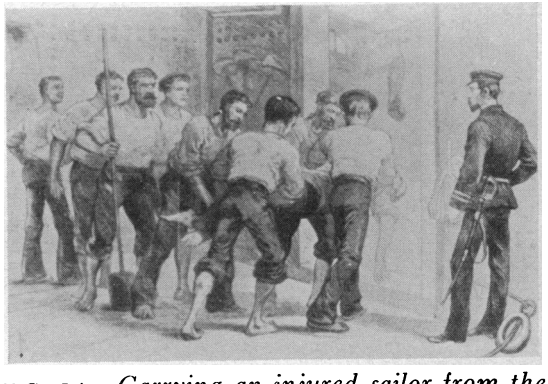

FIG. 14 *Carrying an injured sailor from the upper battery of HMS* Alexandra *during the bombardment of Alexandria, 1881. (Wellcome Institute of the History of Medicine.)*

at the outbreak of war in 1914 found the prospect of casualty management so daunting that he recommended nothing more than first aid during action and the landing of casualties immediately afterwards[61], a return to mediaeval folly which disregarded entirely the lessons of Algiers and the observations of Wilson that immediate treatment saved lives. At Jutland Sir David Beatty watched with mounting apprehension as three of his lightly armoured battle cruisers blew up when German shells struck their turrets, igniting cordite, the flash from which shot down to the magazines, which exploded. The Germans had already learnt the lesson at Dogger Bank the previous year and the gunpowder detonators of their cordite bags were protected in brass containers[62], a precaution that might have helped save the *Hood* from a similar fate in 1941[63]. HMS *Lion,* Beatty's flagship, was hit on the midship turret and, according to Staff Surgeon McLean[64], there were 146 casualties, a casualty rate of 11.9% of *Lion's* complement and a ratio of killed to wounded of nearly 9:1, a reversal of that in sailing ship days. Delay in treatment nevertheless cost some lives. Sixty-four of the 95 killed and 30 of the 51 wounded were burned, and McLean distinguishes between the superficial flash burns of survivors and the severe cordite burns of the fatally injured, which were associated with chest complications. Twenty-five per cent of casualties sustained fractures and 45% soft-tissue injuries, 54% had been injured by splinters—now jagged metal—and in 27% wounds were multiple.

The action over, McLean and Stephens[65] rigged a temporary operating theatre in the captain's bathroom and undertook lifesaving surgery using Listerian antiseptic principles on 28 anaesthetized patients, glad of the assistance of an executive lieutenant since 44% of the medical staff had been lost. Fleet Surgeon Muir[66], of HMS *Tiger,* explains that wounds and burns received in action became septic because, in those coal-burning ships, 'patients are in an indescribably dirty condition, in spite of . . . donning clean clothing before action. . . . The mess decks and accommodation passages are covered with one to twelve inches of water; the men are constantly splashing through this; they are hot and perspiring; the consequence of being struck by a shell is clouds of dust and smoke . . . clothing is scorched'.

Ash and Wakeley[67] described the compound fractures with huge muscle defects, reminiscent of sailing ship days, in patients admitted to the Royal Naval Hospital, South Queensferry. They included patients suffering from nitrous fumes which resulted from incomplete combustion of cordite. The mixture of oxides of nitrogen so formed reacted with the moisture of the respiratory tract to form nitric and nitrous acids, leading to fatal pulmonary oedema, and oxygen does not appear to have benefited the condition[68]. Fairlie[69] drew attention to the latent period before the onset of symptoms and recently Hampton[70] has shown that smoke in the closed compartments of ships causes similar complications, even in the absence of fire. Carbon monoxide was, of course, the other accompaniment of explosions and fires in confined spaces which Ellis[71] has shown was associated with damage by torpedoes in both world wars.

The treatment of burns dominated naval medical literature after the Battle of Jutland, and Wakeley[72], then a surgeon lieutenant, established sound principles based upon the extent and depth of the burn. He used intravenous and subcutaneous electrolyte solutions for fluid replacement and exposed his burns to the open air, condemning picric acid, the local application popular at the time, as toxic and locally destructive. He practised early skin grafting and prescribed

urinary antiseptics, vaccines for persistent infection, and digitalis to support the heart, with excellent results. His principles were years in advance of contemporary thinking and it is noteworthy that Pearce-Gould and Archer[73], who were also temporary naval surgeons, described the cutting of skin grafts under local and regional anaesthesia, a technique 'rediscovered' after World War II. It was also a surgeon who proposed preventive measures; Penfold[74] recommended the wearing of fire-proofed anti-flash masks and gauntlets by guns' crews, which appears to have been somewhat tardily adopted by the authorities. However, this was standard practice in World War II and, where followed, significantly lowered the incidence of burns.

The Second World War

In the Second World War ships had become more technically complex and electronic aids had assisted naval gunners to pinpoint their target, but surface actions brought little change in the pattern of injury, with the solitary exception of burns. This can be attributed directly to the effectiveness of protective clothing, although too often the tropical uniform of shorts and shirt, giving absolutely

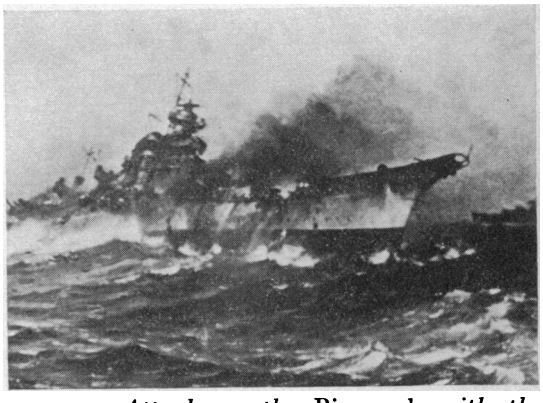

FIG. 15 *Attack on the* Bismarck *with the cruiser* Dorsetshire *in the background. (C E Turner, Illustrated London News.)*

no protection to the wearer, peaked the casualty rate in some instances. In the *Scharnhorst* action of November 1943 anti-flash gear was not worn by the crew of 'X' turret in the cruiser *Norfolk*, all of whom suffered severe burns, but at the Battle of the River Plate in 1939, although HMS *Exeter* took tremendous punishment and had a casualty rate of nearly 23%, with good protection burns were minor. What did change in surface actions was the more favourable rate of killed to wounded (Table III), which can be attributed to a return

TABLE III *Comparison of casualty patterns resulting from surface actions in World War II and World War I*

	Fractures (%)	*Wounds (%)*	*Burns (%)*	*Multiple (%)*	*Shrapnel (%)*	*Casualty rate (% complement)*	*Killed: wounded ratio*
World War II—surface action							
Narvik II (D)	25.5	32.7	3.6	21.8	47.3	6.25	1:1
Onslow (D)	8.3	70.8	–	16.6	100.0	7.74	2:3
Exeter (C)	41.5	36.6	17.7	29.3	63.2	22.59	2:3
Ajax (C)	6.6	93.3	–	20.0	100.0	2.42	1:2
Norfolk (C)	30.2	34.9	34.9	20.9	48.7	8.0	1:5
World War I—Jutland							
Lion (B)	25.5	45.1	56.8	27.4	54.9	11.9	9:1

B = battleship, C = cruiser, D = destroyer

to the principle of immediate resuscitation and surgery for the seriously injured, and ships were far better equipped to do it. For instance, HMS *Warspite* received 59 casualties from destroyers in the second Battle of Narvik (1940). Resuscitation by intravenous transfusion and X-rays of injuries were carried out prior to operation on board the battleship and Beaton, her principal medical officer, even illustrated the X-ray appearances in his journal. Four casualties died almost immediately, but all the rest were transferred to a hospital ship 12 days later in very good shape[75].

Deaths continued to occur from nitrous fumes, toxic smokes, and carbon monoxide poisoning. Desmond and Frazer[76] described a cordite explosion in a gun turret. The survivors reported that after the gun had fired flames shot from the breech when it was opened, filling the turret. There was an orange-red, intensely hot, central core surrounded by a multicoloured aura which merged into a peripheral zone of fine particulate smoke. Sailors in the central core were severely burned and those in the outer zone suffered toxic and respiratory complications after a latent interval of 2–24 hours. Ellis[71] reported Haines's description of the lung histology in such cases: acute vasodilatation, ruptured lung alveoli, and eosin-staining, coagulated oedema fluid in some alveoli, similar to appearances reported in the traumatic wet lung of Vietnam casualties. Wakeley[77], now a surgeon rear-admiral, understanding the significance, treated his burns cases with cortisol, and Surgeon Lieutenant-Commander John Bunyan[78] invented the envelope method of treating burns.

Two new factors in World War II were the magnetic mine and air bombardment. Mines produced a characteristic pattern of injury, with simple lower extremity and lower dorsal spine fractures predominating. Burns and blast injury were surprisingly rare. The ratio of killed to wounded was approximately 1 : 1. That was also generally true of torpedo attacks, but in both cases gas poisoning appears to have been a not uncommon accompaniment. For instance, in HMS *Phoebe* casualties suffered from nitrous fumes, in HMS *Albatross* from nitrous, carbon monoxide, and carbon dioxide poisoning, and in HMS *Stevenstone* from fumes of methyl chloride resulting from damage to the ship's refrigeration system[79].

Air attack, however, changed the whole character of war at sea. Surgeons in World War I had brief, intensive periods of activity and prolonged inactive intervals. The surgeons in World War II, particularly if accompanying Atlantic, Mediterranean, or Arctic convoys and later in the Pacific, lived under constant threat of sudden unexpected air bombardment which might be continued for days on end. The explosive effect of a bomb between decks was devastating, fractures and blast injuries predominating, but splinters from near misses would strike the ship some 20 feet above the water line and even penetrate the ship's side, causing multiple shrapnel wounds from the waist up[80]. The aircraft carrier *Illustrious* was under almost continuous bombardment in the vicinity of Malta from 10th to 19th January 1941 and sustained 276 casualties, of whom 148 survived. Her principal medical officer, Keevil[81], whose magnificent action medical organization undoubtedly reduced the mortality rate, described in his journal the great severity of wounds complicated by blast from bursting bombs, although burns were minor because of the enforced use of protective clothing. One precaution he did not take, however, was to guard against damage by broken glass in the sick bay, a danger to which Wilson[82] had drawn attention in 1846. Keevil's description of the dismemberment,

evisceration, death, and destruction in the hangar is analogous to that on the gun deck of HMS *Genoa* after the Battle of Navarino in 1827 described by Charles McPherson[15], and it is interesting to note that *Genoa's* killed to wounded ratio ran contrary to the usual pattern and was 1:1, like that of *Illustrious.*

Toll of the sea

Yet, when all is said and done, it is the cruel sea itself which takes the greatest toll. The Spanish Armada survived disease amongst its crews, it escaped from the English in the Channel, it survived the fire ships at Gravelines, yet when a south-west gale drove the proud galleons into the North Sea over half the vast Armada was lost. Lewis[83] has pointed out that in the wars with France from 1797 to 1805 only 10 ships were lost as the result of enemy action, while no less than 91 foundered or were wrecked. If we now exclude from the Jutland casualty figures ships that were sunk during the action, the casualty rate is reduced from 11.14% to 0.83% and the ratio of killed to wounded from 9:1 to 2:3. In World War II Talbot[84] concluded that approximately two-thirds of all fatalities in ships of the Royal Navy resulted not directly from injuries sustained during enemy action but from failure to survive the marine environment[85]. Survivors may have absorbed oil and detergents into their lungs in the vicinity of the ships, blast injuries of abdomen and lungs certainly resulted from depth charges exploding in the area, but we now know that hypothermia accounted for the majority of the lives lost. It is towards the prevention of hypothermia and the effects of noxious gases in closed compartments that attention must now be directed if lives are to be saved in future conflicts.

Epilogue

Mr President, you have done me the honour of electing me Thomas Vicary Lecturer. It is also an honour for the Service I represent. I hope therefore that the contributions made by naval surgeons during four centuries of naval warfare have been such as would have won the approval of Thomas Vicary and his colleagues, Thomas Gale and Wylliam Clowes, a naval surgeon himself, who together founded the school of English surgery.

In my search for historical details I have received help from sources too numerous to mention, but several individuals have made my task easier. They include Miss V Riley, of the Naval Historical Library, Mr D V Proctor and Mr A W H Pearsall, of the National Maritime Museum, Mr E H Cornelius, Librarian of the Royal College of Surgeons, Mr S Watkins, of the Wellcome Institute of the History of Medicine, Mr C T Parsons, Librarian, Royal Naval Hospital, Haslar, Mrs J Reynolds and Mr H Tomkins of the Institute of Naval Medicine, Miss J Orman, of the Department of the Medical Director-General (Naval), and Capitaine de Vaisseau Hervé Cras of the Musée de la Marine, Paris.

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